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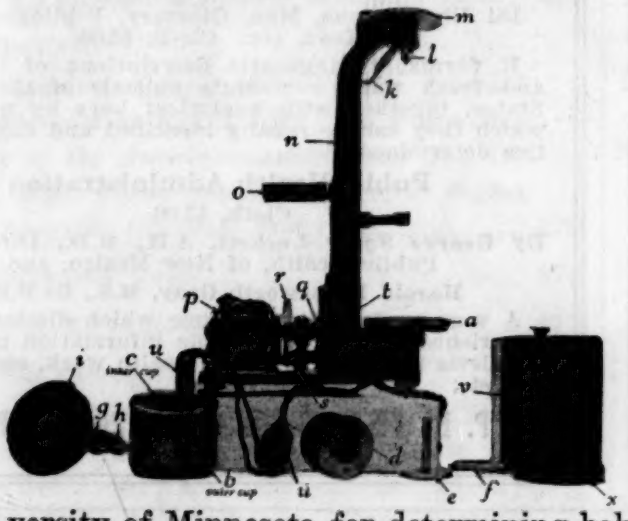

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THE HISTORY OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE*

ORIGIN: EARLY EVENTS

THE American Association for the Advancement of Science had its inception in geology, and by the geologists of the New York Geological Survey. A bronze tablet on an old residence in Albany, New York, corner of Hudson Avenue and High Street, bears this inscription:[1]

> In this house, the home of
> Dr. Ebenezer Emmons,
> the first formal efforts were made, in
> 1838 and 1839, toward the organization of the
> Association of American Geologists
> the parent body of the
> American Association for the
> Advancement of Science
> by whose authority this tablet is erected
> 1901

The several narratives of the early history differ only with reference to the credit for first suggesting the conference of American geologists. In a memorial to Lardner Vanuxem (1, 1848, 91–2) James Hall gave the credit to Vanuxem, and indicated that the purpose of the conference was the harmonizing of the Paleozoic stratigraphic nomenclature. At the Albany meeting of the association in 1856, Hall again describes the circumstances of the conversations, in 1838, 1839, of the New York Board of Geologists (10: 231).

The report of the committee on the Emmons House memorial (50: 392) quotes a letter, of date November 9, 1838, from W. W. Mather to Emmons, suggesting a conference, but saying that he had received the idea from Edward Hitchcock. And Hitchcock also recounted the early events in his address at the inauguration of the Geological Hall in Albany, Au-

* Address at the Seventy-fifth Anniversary Meeting of Association, Cincinnati, December 29, 1923.

[1] The association is indebted to Dr. John M. Clarke, for the conception and execution of the memorial project. The proposal was made through Section E in June, 1900. (49: 383). The expense was borne by a member and friend of the association, Hon. T. Guilford Smith. The story of the memorial tablet is told in the New York State Museum Bulletin, No. 52, pages 452–456.

Numerals in parenthesis, unless otherwise noted, refer to volume and page of the Association Proceedings.

gust 27, 1856, and stated that his frequent suggestions of a meeting were "a sort of hobby in my correspondence."

The correspondence leading to the Philadelphia meeting was conducted by Vanuxem. In a personal letter Dr. Clarke writes, "Vanuxem was the gentle spirit in the Board of New York Geologists, who was used as an intermediary and propitiator in all their affairs."

As result of suggestions and correspondence, covering a period of two years, the gathering was held in Philadelphia, and the Association of American Geologists was organized in the Hall of the Franklin Institute, April 2, 1840. An account of this initial meeting in the *American Journal of Science* (39, 1840, 189–191) gives the names and residence of 18 men who participated in the meeting, of whom five represented the New York Survey. Edward Hitchcock was the chairman.

At the third meeting, in 1843, the geologists' association was widened in scope and the name changed to the Association of American Geologists and Naturalists. A report of the work of the three meetings gives a list of 77 names of persons who had "attended the meetings or presented communications." Sixteen of the names carry the prefix "Prof.," and four that of "Rev.," the latter including Edward Hitchcock, the first president. It appears that in those days geology included about 5 per cent. of theology. In England there was a greater intimacy between scientific and ecclesiastical interests when the British association was organized, for more than one fourth of the members of the scientific subcommittees were clergymen, including the eminent geologists Buckland and Sedgwick.

The geologists and naturalists held annual meetings, some accounts of which were published in the *American Journal.*[2]

In 1847 it was decided to further widen the membership, and the parent association was enlarged into our present association, at Philadelphia, September 20, 1848. The constitution ("Rules") then adopted had been drafted by a committee consisting of H. D. Rogers, Benjamin Peirce and Louis Agassiz, and was modeled after that of the British association, the latter having been organized in 1831. It is inferred that Agassiz, having worked in England and having attended the British association, arriving in America in 1846, was influential, if not dominant, in the organization of the broader association, and in the formulation of its "objects and rules."

William C. Redfield, the first president, whose special interest was in meteorology and physics, appears to have been interested in the expansion of the society. In his memoir of Redfield, 1887, Denison Olmsted says, "Redfield, who was the first to suggest the idea of the American association on its present comprehensive plan" (11: 9).

In an article in volume 40 of the Proceedings, pages 39–47, G. Brown Goode describes the National Institution for the Promotion of Science, which was established in Washington three weeks after the geologists' association was organized in Philadelphia. It was chiefly supported by government officials, and held a national scientific congress in Washington in April, 1844, a few weeks preceding the meeting of the geologists and naturalists in the same city. Goode gives the list of 43 papers at the congress in several branches of science. The institution was inactive after 1845, and passed out of existence in 1861. The author aimed to show that the Washington institution was one of the parents of the American association, by its example of wider scope. His argument is inconclusive and his statements regarding the name of the American association contains two errors. It may be suggested that the Washington institution and its congress were an effect instead of a cause.

It is quite certain that the name and the rules were borrowed from the British association. The Association of Geologists and Naturalists was the parent, and the British association was godfather of the American association. The parental relation was officially recognized in 1874 (23: 160), by ordering the inclusion in the volumes of proceedings of data relating to the eight meetings of the early society.

In his presidential address in 1851, A. D. Bache spoke in approval of the genesis of the association through geology, adding, "Thus, far deeper, morally, than the comparative depths which they explore, the geologists laid the foundation of the American Association" (6: XLVII).

The association was evolved from the earlier society without any recorded opposition from any quarter; although Bache in his address casually speaks of opposition. In this respect it was more fortunate than the British association. There were no national societies to be jealous, and the strong local societies of the time appear to have welcomed the new, comprehensive and peripatetic association.

In notices of its first meeting the *American Journal*

[2] Following are complete references in the *Am. Jour. Science* to the eight meetings of the early association: First meeting, Volume 39, 1840, pages 189–191; second meeting, Volume 41, 1841, pages 159–189; third meeting, Volume 43, 1842, pages 146–184; fourth meeting, Volume 45, 1843, pages 135–165, 310–353; fifth meeting, Volume 47, 1844, pages 94–160, 247–278; sixth meeting, Volume 49, 1845, pages 219; seventh meeting, Volume 2, 1846, pages 144, 441; eighth meeting, Volume 4, 1847, pages 146, 427–429; eighth meeting, Volume 5, 1848, pages 102–116, 243–250; first meeting of the American Association for the Advancement of Science, Volume 6, 1848, pp. 393–401.

referred to the association as the "Amer. Assoc. for the *Promotion* of Science." Some members will agree that such would have been the preferable title, for significance, euphony and originality. A statistical psychologist might calculate the time and energy that has been wasted in the writing of our long title many times a year, for 75 years, by several thousand people. The organizing committee, instead of imitating the British society, might have made the name "American Science Association." Even now if we could overcome our excess of reverence for usage and antiquity we might abbreviate the name for the convenience of posterity.

At the Baltimore meeting, 1858, a committee was appointed to make an abbreviation of the title. In 1860 the committee proposed (14: 247) that in the abbreviation the words "for the Advancement" be neglected, and the formula should read "Am. Asn. Sci." To the ear this is even less agreeable than to the eye, and it is not surprising that no later mention, or use, was made of it. Instead, the four initial letters have long been in common use.

Many personal and social incidents of the early meetings would be very interesting to us after the lapse of 75 years. But the records, archives and correspondence are not available, if in existence. The Proceedings volumes are properly formal, containing the personnel, business transactions and the scientific papers, but no incidental matter.

The year 1848 fell in a period of intellectual ferment and political unrest, with revolutionary movements in Europe and America, and many historical events are listed in that year. The Mexican War had just closed, and the treaty signed in February annexed a vast western territory. The discovery of gold in California and the postal convention between the United States and Great Britain were important economic events. Exploring expeditions gave geographic interest, while the completion of the High Bridge aqueduct in New York City was an engineering event. Two psycho-religious incidents were the first public demonstration of spiritualism, and the vitalizing of Mormonism by the persecution at Nauvoo, Illinois. An important sociological event was the initiation of the movement for the enfranchisement of women by the first woman's-rights' convention, in July.

ORGANIZATION; ADMINISTRATION

The "objects and rules of the association," with 20 divisions as adopted in 1848, were changed to "constitution" in 1851, with 21 items (6: X). In 1856, a new draft was adopted, with amendments in the later years. In early years, 1851–1873, some of the legislation was carried under a peculiar heading, "Resolutions of a permanent and prospective character," although some of the resolutions were of transient effect. In addition a compilation of all previous resolutions is found in some volumes. These two categories were necessary in the administration because of the lack of flexible by-laws.

A committee on revision of the constitution of 1872 reported adversely on certain points in question, but added, "But they also have to report that they find several violations of the constitution of common occurrence, and that they think a strict adherence to be of vital importance to the association" (21: 279). Signed, F. W. Putnam, G. C. Swallow, for the committee. This suggests that the "constitution between friends" was not an object of reverence even in the former days.

Apparently the administrative troubles were acute, for the next year another revision committee was appointed, which submitted in 1874 a new draft of 38 articles. In their analysis of the many changes the committee said, "The constitutional troubles, which for many years have often caused the meetings to assume the temporary character of a parliamentary body, have been finally disposed of . . ." (23: 150–151). This radical revision was debated several days, and on the fifth day, August 17, 1874, was adopted (23: 167). The former lists of resolutions were of course omitted. The annual dues were increased from two to three dollars.

At this meeting, 1874, a report was made of the incorporation of the association under laws of the Commonwealth of Massachusetts (23: 46–47).

From time to time the constitution of 1874 received changes, especially in 1881, 1886 and 1887 (36: 344). In the latter year, at the first New York meeting, the "standing committee" was changed to "council," and the office of secretary of the council was created. Minor changes were made occasionally, and several in 1899. In 1903, important amendments provided for five-year terms for the sectional officers, to give greater efficiency by longer official experience; also providing that three of the nine elective members of the council should be chosen each year for three-year terms, thus giving more stability to the council membership.

With the above changes, and some supplementary rules of the council, the 1874 form of constitution stood until 1920. The association worked under that draft for 46 years. As there were no by-laws for the details of administration, the constitution became burdened and complicated with items of procedure. Moreover, the changes in the character and work of the association, and its relations to the many new technical societies, made the constitution ineffective. It stands to the credit of the association and its governing body that its work was conducted so long, so successfully and smoothly, with rapidly changing con-

ditions of American science, under an archaic and outgrown set of rules.

In 1917, the committee on policy authorized a subcommittee, consisting of J. McK. Cattell, H. L. Fairchild and D. T. MacDougal, to make a radical revision of the rules. The new and greatly simplified constitution, of 11 articles instead of the former 39, was unanimously adopted at the St. Louis meeting, and went into effect January 3, 1920. This brief constitution, of fundamentals, is accompanied by a more detailed set of by-laws and rules of procedure, itemized under 11 sections. For comparison, the old and the new constitutions and the new by-laws are printed in the volume of Summarized Proceedings, 1921, pages 10–27. Future changes are made easy, by requiring for amendments to the constitution only unanimous consent at any general session of the association, or a majority vote at two successive annual meetings; while the by-laws and rules may be changed at any time by vote of the council.

While the plan of organization of the association and of its activities has not been greatly changed by the new rules, a few modifications are important and worth noting. The council is made more effective by omission from its membership of past-officers; and by the continued inclusion of representatives of the "affiliated" societies. The "general committee" is abolished. Under the former régime its function was merely to elect officers and to determine the places of meetings, while its personnel was identical with that of the council except for the addition of an extra representative from each section. The annual dues of three dollars since 1874 have been made the more convenient unit of five dollars, securing greater respect for the society and increased resources.

By 1890 the multiplication of special technical societies had become a recognized potential danger to the association, and in 1895, at the Springfied meeting, a committee was appointed to "enunciate the policy of the association" and to confer with the affiliated societies. This committee on the policy of the association, as first appointed, consisted of the president and permanent secretary and one representative from each of the sections. On account of its large and changing membership, and scanty attendance at the sessions, the work of the council has been in large degree passed over to the policy committee. As originally constituted the committee was too large for efficiency, and in 1897 it had only seven members, and a small membership in later years. Under the present régime the administrative function of the committee is officially recognized by naming it the executive committee of the council. The committee holds at least two meetings between the stated annual meetings, and because of the infrequent meetings of the council is compelled to act on imperative matters and to assume large responsibility. The efficiency of the committee has been partly due to its small membership and to its continuity of service.

Another important change in the organization of the association was necessitated by its vast territory. Two regional divisions of the association are established: the Pacific Division and the Southwestern Division. At the Cleveland meeting, 1912, a large committee was named to plan for a proposed meeting in San Francisco. This meeting was held in 1915, and brought into harmonious relation the 12 special societies then existing on the Pacific coast (SCIENCE, 41: 638). From this meeting has developed the Pacific division of the association, which held its first meeting in San Diego, in August, 1916, with 13 affiliated societies. This division covers territory, in addition to the Pacific coast states, of Alaska, British Columbia, Idaho, Nevada, Utah and Mexico (except Sonora and Chihuahua) and the Pacific islands belonging to the United States. The Southwestern Division, organized in April, 1920, at Tucson, Arizona, includes Arizona and New Mexico, the portion of Texas west of the Pecos River, and the Mexican states of Sonora and Chihuahua. The two divisions have their own rules, subject to ratification by the council, or by the executive committee, and are practically autonomous. (The rules of the two divisions are printed in the Summarized Proceedings, 1921, pp. 28–38.)

Local "branches" of the association were authorized in 1913 (65: 464), and are very desirable. One is now recognized, at Pennsylvania State College.

Until 1882 the scientific work in the meetings was conducted by two general sections, with vice-presidents, and a variable number of subdivisions, with chairmen. At the Montreal meeting in 1882 a plan of nine lettered sections went into effect. By 1915 the number of sections had increased to 12. At the present time 16 sections are recognized.

In the 75 years of the association two periods may be noted—the first extending from the date of organization to about 1898, the half century during which the association was the national representative of science in America. The second period is the last 25 years, during which the special societies are numerous and strong, and the technical work is carried by 93 "affiliated" or "associated" organizations, the association being the correlating and unifying body and the recognized representative and spokesman.

In 1891 seven societies met with the association. In 1899 the affiliated societies were recognized in the constitution, and in 1901 they were represented on the council. In later years the number of national societies in convocation has been: 30 in 1910, 43 in 1916 and 28 in 1920. At present 41 national societies and 12 state academies are listed as affiliated, and 40 societies as associated (Sum. Proc., 1921, 24–26). In

order to secure harmonious relation and cooperation between the sections and the societies the sections of the association are expected to suspend their technical programs when the corresponding societies meet in conjunction. Joint programs are frequent and very desirable.

If a biologic simile is permissible, it may be said that the association attained reproductive maturity at the age of 50 (1888), and gave birth to numerous progeny. But this fertility has not produced exhaustion and dissolution, for the association is vastly larger, stronger and more active and influential in later years. Perhaps some of the lusty offshoots are not always as deferential to their aged and honored parent as filial duty would imply; but as a whole the great family is quite harmonious.

HERMAN L. FAIRCHILD
UNIVERSITY OF ROCHESTER

(To be continued)

THE THEORY OF NERVOUS ACTIVITY[1]

IT is my intention to present to you the result of work carried out in my institute dealing with the ionic theory of stimulation.

Every mathematical theory is important for science in so far as it is capable of correlating in a quantitative way a series of natural phenomena and in so far as it permits the predicting of existence of phenomena not yet observed. The latter requirement constitutes the test of a theory, and if the predictions are realized through experiments, then the correctness of the theory is established. From this viewpoint, the theory appears as a guide to the investigator and opens up to him new avenues for quantitative experimentation.

The ionic theory developed by us stood the mentioned test, and I should like to present in a simple form the physico-chemical facts, omitting all mathematical development. For lack of time, it is not possible to present all our investigations into the mode of action of all sense organs and, therefore, I shall present as an example that part of the work which has attained its fullest development, namely, that dealing with peripheral colorless vision (when color is not differentiated). In this field the predictions of the theory were most interesting. The theory developed by us is based on two observations made about 20 years ago, one by Jacques Loeb and the other by Nernst. Starting from entirely different premises, they arrived at a conclusion that in the nerve and in the muscle the change from the state of rest to that of excitation is brought about by changes in the ionic concentration of the medium.

These observations were made the basis of our investigation into the general principles of the theory of excitation. We were then able to demonstrate that in all organs, under all conditions, excitation is possible only as a consequence of changes in ionic concentration of the medium. Whenever these changes are not present, excitation is not possible.

Bearing in mind these conclusions, and adding only one assumption, namely, that in the tissues the concentration of ions is small, we formulated a general law of excitation for the threshold of irritability—a law which served as a generalization of the laws presented by Loeb and by Nernst. Calculating in every case the possible changes in ionic concentration, we were able to explain the laws of Pflüger, to develop further a theory of nervous excitation, to formulate a theory of muscular excitation, a theory of vision, a theory of hearing and of taste, and very recently, it was possible to go further and to develop laws of the function of the central nervous system (of the brain).

Passing to the question with which we are principally concerned to-day, namely, the question of the ionic theory of vision, I should like to point out that we shall discuss principally the problem of peripheral vision when the function is limited only to the rods in which the decomposition of the pigment takes place.

We can imagine the process in the following way. Decomposition of the pigment takes place in the rods. This is a purely physico-chemical reaction, which results in ionization. The ionized substances are removed partly through diffusion and partly through chemical reactions which are followed by restitution of the pigment. This restitution should proceed with different velocity, depending upon the presence or absence of light. In order to coordinate all these conditions in mathematical terms, it was necessary, first of all, to explain the connection existing between the velocity of the chemical reactions, the coefficient of absorption of light, the concentration of substances and the intensity of light. This was done by us in a series of investigations and it was demonstrated in 1907 that the photochemical effect does not depend on the wave lengths but is proportional to the quantity of the absorbed energy. The experiments showed also that in photochemical reactions the ionization is in direct proportion to the quantity of decomposed material. This applies alike to solid and liquid substances. Thus, it was realized that the visual pigment, in the process of decomposition, causes stimulation of the nerve endings and consequently creates excitation. If all these considerations are expressed mathematically and if a few very simple mathematical operations are performed, then, at a given time, t,

[1] Read at the Cincinnati meeting of the Zoological Society in conjunction with Section F of the American Association for the Advancement of Science and in association with other biological societies on December 28, 1923.

the concentration of products of photochemical reaction in the pigment C_1, depending on the action of light, is shown by the following expression:

$$C_1 = \frac{\alpha k J C}{\alpha k J + \beta}\left[1 - e^{-(\alpha k J + \beta)t}\right]$$

C stands for the concentration of the pigment.
α and β are constants.
k = coefficient of absorption.
J = intensity of light.

The general law of excitation postulates for vision that the quantity of decomposition products C_1 (ions) must exceed a certain limit "A," in order that excitation may take place.

The simplest deduction, then, was that when the quantity of energy absorbed by the layer of pigment in the retina was the same for different colors, then the intensity of light at peripheral vision was constant. This deduction and all subsequent deductions were completely verified by the experiments.

In order to show the limit of possible deviations from the theory, I shall take the case of intermittent light with such a number of interruptions that the light just begins to appear continuous. According to the theory, the number of interruptions N must be connected with the values mentioned above in the following way:

$$\frac{(N - N_0) \cdot \sqrt{4\pi^2 N^2 + \beta^2}}{\alpha k J} = B = \text{Const.}$$

N_0 is a constant.

The results of the experiments vary between 0.42 and 0.43.

It is known by experience that the eye, exposed for a long time to light and transferred into darkness, does not at once distinguish objects and that the sensibility increases gradually and finally the eye is capable of seeing. It follows from the theory that these changes may depend upon the variations in the concentration of the visual pigment in the eye. Assuming that the reaction of restitution of pigment in darkness possesses the simplest character, namely, that a single molecule of the decomposition product is reconverted into a single molecule of the pigment, then the sensitiveness of the eye E at different intervals in darkness may be expressed by the following formula:

$$E = E_0 - E_0' e^{-\gamma t} \qquad (I)$$

E_0 and γ are constants.

E_0' depends upon the intensity of the acting light and at infinitely high intensity $E_0' = E_0$.

At the intensity equal to 0^0, $E_0' = 0$.

This conclusion was reached in 1914.

The experimental data existing in the literature showed discrepancies from the theory. Assuming that all variations in sensibility, according to our theory, depended on variations in the quantity of pigment in the membrane, it followed that the discrepancies between experiment and theory were due to the fact that variations in the sensitiveness of the brain centers were not taken into consideration and that the fatigability of the centers was not considered. This explanation was offered by Froelich. However, another explanation is possible, namely, that the older experiments were not carried out with sufficient care. This explanation was advanced by us in our first paper dealing with the problem of adaptation. The last three years were devoted by us to testing this assumption.

If you will take into consideration that every observation reported is the average of hundreds and that there were required a great number of single observations with varying time of adaptation and a great many individuals were studied for each experiment, then you will understand that there were made more than several thousand single observations in order to arrive at one formula. The formula (I) proved correct and hence it is possible to explain the discrepancies of the older observations.

From the present theory there follows what seems a paradoxical conclusion—that in fatigue, with the change of sensitiveness of the organ of vision, the brain centers are not fatigued. Because of the importance of this conclusion for physiology, it was tested directly. As soon as the eye adapted itself to darkness, it was subjected to electrical stimulation acting directly on the nerve. It was then found that when exposed to light the organ of sight showed a different sensitiveness to stimulation by light than it did when left in darkness and that the sensitiveness could undergo thousandfold variations. On the other hand, the sensitiveness to electric stimulation remained the same in both cases. From this observation the conclusion naturally follows of the indefatigability of the brain centers.

If all which was said is correct, and applicable to all nerve centers, we may conclude that in the absence of stimulation, the organism will not fatigue. Experiments carried out under special conditions demonstrated that the nervous system is preserved from fatigue for extended intervals if the periphery of the retina only is stimulated and if all other irritations are avoided. In our institute, when the experiments on adaptation lasted from 12 to 24 hours, individuals did not experience the least fatigue, as if unconscious of the flight of time. At first it might seem that if all external irritation were removed, the organism would not fatigue at all. However, under such conditions, the periphery would convey to the centers no impulses at all and the activity of the centers would be suppressed and the organism would

lapse automatically into a condition approaching sleep. Experiments have confirmed this conclusion, also. It is interesting that this indefatigability of the nerve centers must be in close connection with the periodicity of the function of the centers. According to our observations and to those of other workers, periodic chemical reactions must take place in these centers. These reactions in their turn bring about periodic electromotive forces.

This parallelism between indefatigability and periodicity of function is best illustrated on the heart and on respiration.

The entire theory is based on the premise that the difference in the intensity of perception, in general, depends on the difference in the ionic concentration in the retina. Here arises a contradiction with the basic physiological conceptions.

If the intensity in stimulation and the magnitude of excitation depends upon the concentration of the ions in the retina, then the nerves ought to be in a different state of excitation depending on the ionic concentration. On the other hand, we know that the nerve may be either in a state of excitation or non-excitation. Consequently, the state of excitation of a nerve can not be of varying degrees. The explanation of the seeming contradiction is very simple. It is necessary to bear in mind that the retina consist of individual cells and that light, on the other hand, according to the present conception of the physicist, possesses a corpuscular structure and that there exists, as it were, a number of small balls, each carrying a definite quantum of energy on striking the retina. The number of these balls, quanta of energy, gives us the perception of the intensity of light. Consequently, the number of stimulated rods and the number of stimulated nerve fibers determine the sensation of intensity of light. From this it follows that when the number of the stimulated units is identical, the intensity of perception will always be constant. Also, if the same number of stimulated units will be situated, on either a small or a large surface of the retina, the effect will remain the same. All these conclusions were corroborated. You see that the present theory not only gave a quantitative coordination of the facts already known, but also was instrumental in the discovery of new facts. This is all that a physico-chemical theory is expected to accomplish.

P. LASAREFF

PLANS FOR THE ENLARGEMENT OF THE MARINE BIOLOGICAL LABORATORY

IN response to the request of the editor the following statement is made:

The enlargement of the facilities and endowment of the Marine Biological Laboratory is a matter of interest to the scientific public in a special sense, because its ownership and control are vested in the biologists of the country in precisely the same sense as their national biological societies. For this reason, also, the development of the laboratory is a matter of interest to all institutions engaged in biological research; the facilities of the laboratory are at their service and constitute an enlargement of their own laboratories and equipment. The Marine Biological Laboratory thus helps towards raising the research opportunities of the smaller institutions more nearly to the level of the larger and better equipped ones. Through its system of subscribing and cooperating institutions the laboratory provides for a nominal sum research opportunities that would cost each institution many times the amount to provide independently. This is important even for the largest institutions, and indispensable for all the smaller institutions that aim to maintain the research spirit of members of their staffs.

Up to the present year the Marine Biological Laboratory has been supported by fees for working places, by sales of biological supplies, certain minor sources of income, and by a contribution of $20,000 a year from the Friendship Fund endowed by Mr. C. R. Crane, president of the board of trustees of the laboratory. For about five years the demands for accommodations have far exceeded the capacity of the laboratory. Plans for enlargement have been in preparation all this time, and, indeed, for a longer period.

At the beginning of this year the laboratory received direct gifts amounting to $1,400,000 (from the Rockefeller Foundation $500,000, Mr. John D. Rockefeller, Jr., $400,000, The Friendship Fund $400,000, and the Carnegie Corporation $100,000), and an undertaking from another source to furnish additional sums needed to cover the increased cost of building arising since the original plans were prepared. Of the direct gifts, $900,000 has been placed in trust as endowment, the balance being available for building. The receipt of these gifts was due to the hearty cooperation of scientific men supported by the recommendations of the National Research Council.

The greatest needs foreseen by the management of the laboratory, apart from mere expansion, were the increase of facilities for all the more delicate and precise forms of biological experiment, comprised largely in the fields of biochemistry and biophysics, and for enlargement of the library. Advantage was also taken of the situation to provide an adequate auditorium for the evening lectures on research topics that have been a conspicuous feature of the summer session for many years.

Ground was broken for the new building in March; it is expected that it will be completed and equipped in less than a year. The building will be of heavy fireproof construction, calculated to be free from disturbing vibrations. Provision for experiments with electricity, light, X-rays and temperature will be unusually complete. Extensive additional equipment for physiological work is also provided. The building will include one general and fifteen private biochemical laboratories, two general biophysical laboratories, one general and twenty-seven private laboratories of the biological type, but arranged *en suite* with the biochemical laboratories, five experimental dark-rooms, a suite of four rooms for X-ray work, a photographic and developing room, draughting room, three special balance rooms, administration offices and committee rooms, a galvanometer room, and (in the basement) store-rooms, storage battery room, refrigerating equipment and constant temperature rooms, and a machine shop. The library wing will have stock rooms with capacity of about 100,000 volumes, a large reading room and study rooms, and librarian's offices. The auditorium will seat 545.

Future needs have been anticipated to some extent in the plans and it is hoped that the new accommodations added to those already in existence will be adequate for some years. The administration of the laboratory looks confidently for the continuation of the support so generously extended for many years by the cooperating institutions, seventy in number in 1923, and for the moral backing of the biologists of the country. The laboratory will have more to offer; if support was deserved before, it will be more so in the future. The responsibility for developing the laboratory as one of the chief centers of biological research of the world rests squarely upon the shoulders of the biologists and the research institutions of the country.

FRANK R. LILLIE,
Director

SCIENTIFIC EVENTS

BRITISH BOTANICAL CONFERENCE[1]

IN view of the fact that many overseas botanists may be expected to visit England this year in connection with the British Empire Exhibition at Wembley, an Imperial Botanical Conference will be held at the Imperial College of Science and Technology on July 7–16. The arrangements for this conference are in the hands of an executive committee of which Sir David Prain is chairman, Dr. A. B. Rendle, treasurer, and Mr. F. T. Brooks, secretary. The preliminary program shows that discussion will be arranged upon general topics likely to interest both home and overseas botanists. Thus the promotion of a botanical survey of the empire is to be introduced by Dr. A. W. Hill, Mr. A. G. Tansley and a number of overseas botanists are to discuss vegetation surveys and training in field geology; Professor R. H. Biffen introduces the subject of plant breeding, Professor Percival the importance of selection. Plant physiology is represented by discussions upon cold storage of apples and crop physiology; under plant pathology, tropical experience will be utilized in the discussion of sugar-cane mosaic, bud-rot of coco-nut, and brown bast of rubber, whilst the relations of plant pathology to genetics and to silviculture will be considered in separate discussions. Professor J. B. Farmer will open a discussion upon the important question of interchange of staff and post-graduate students between overseas and home universities and the desirability of providing further facilities for botanical research within the tropics and dominions. The program outlined is certainly of great imperial significance, and it is only to be regretted that the executive has not seen its way to bring some of these problems before a wider overseas audience in the conference halls at Wembley itself. Whilst the opportunities for meeting and discussion provided by the conference will no doubt be welcomed by overseas botanists, there is no doubt that the occasion is peculiarly appropriate for the numerous home botanists, many of whom will be deprived of their usual annual opportunity for botanical "shop" with their colleagues by their inability to attend Section K at its distant rendezvous in Toronto. All such botanists will be very welcome at the conference, and they are asked to notify Mr. F. T. Brooks, 31 Tenison Avenue, Cambridge, of their intention to be present. A subscription of one pound toward the expenses of organization is being asked from those proposing to attend.

[1] From *Nature*.

FOURTH INTERNATIONAL CONFERENCE ON SOIL SCIENCE

THE International Conference on Soil Science, to be held in Rome from May 12 to 19, will be the fourth of a series. The first conference was held in 1909 in Budapest, the second in 1911 in Stockholm and the third in 1922 in Prague. The organizing committee distributed last February a provisional program of the conference, which promises to be important.

The Italian Minister of National Economy, Professor Corbino, has promised to be the honorary chairman. The conference will be held at the International Institute of Agriculture in Rome.

Subscriptions are being received from all parts of the world and the number of communications and reports to be presented amounts already to over 200.

These papers concern fundamental questions and will help to show the intimate relationship between soil science and agricultural industry.

The proceedings of the conference will be published in the form of a volume of about 1,000 pages, containing all communications, reports, memoirs, discussions, etc., illustrated with diagrams, graphs, figures and maps and will be useful to scientific institutes and laboratories dealing with agriculture, for agricultural experiment stations, agricultural colleges, fertilizer manufacturers, irrigation and reclamation engineers, etc.

The price to members for copies of the proceedings is 15s., and to others 30s. Further particulars may be obtained from the Organizing Committee of the Fourth International Conference on Soil Science, International Institute of Agriculture, Villa Umberto I, Rome, 10.

THE COMMITTEE ON GRANTS OF THE AMERICAN ASSOCIATION

THE Committee on Grants of the American Association for the Advancement of Science has elected as chairman of the committee Dr. David White, of the U. S. Geological Survey. The membership of the Committee on Grants for the current year is as follows:

David White (1924) (for Geology), *chairman*; U. S. Geological Survey, Washington, D. C.

B. M. Davis (1927) (for Botany); University of Michigan, Ann Arbor, Mich.

W. D. Harkins (1926) (for Chemistry); University of Chicago, Chicago, Ill.

C. J. Herrick (1924) (for Neurology); University of Chicago, Chicago, Ill.

Aleš Hrdlička (1927) (for Psychology, Anthropology, Education, Economics); U. S. National Museum, Washington, D. C.

E. L. Nichols (1925) (for Physics); Cornell University, Ithaca, N. Y.

Frank Schlesinger (1926) (for Mathematics and Astronomy); Yale Observatory, New Haven, Conn.

H. V. Wilson (1925) (for Zoology); University of North Carolina, Chapel Hill, N. C.

Applications for grants from the association should be addressed to the permanent secretary's office, by which they will be promptly transmitted to the members of the Committee on Grants. The appropriation of grants for the current year has been allotted and new applications will be considered as applying for the calendar year 1925. A list of the grants for 1924 has been published in SCIENCE for March 28.

THE INSTALLATION OF THE JOHNS HOPKINS CHAPTER OF SIGMA XI

THE installation of the Johns Hopkins Chapter of the Society of the Sigma Xi was held at the Rennert Hotel, Baltimore, Md., on February 29. The meeting was called to order by President Richtmyer, of the national society.

Dean Ellery, national secretary, read the petition for a chapter at the Johns Hopkins University, and reported that the petition had been unanimously granted at the convention in Cincinnati. President Richtmyer spoke briefly concerning the purposes of the society and then declared the Johns Hopkins Chapter established with the following as charter members:

J. J. Abel
J. S. Ames
E. A. Andrews
W. S. Bear
F. H. Baetjer
E. W. Berry
J. C. Bloodgood
C. G. Bull
G. H. Cartledge
A. G. Christie
W. W. Cort
R. P. Cowles
T. S. Cullen
S. R. Damon
Knight Dunlap
E. C. Faust
W. W. Ford
J. C. W. Frazer
J. E. Gilpin
J. H. Gregory
R. W. Hegner
W. N. Hess
W. H. Howell
L. S. Hurlburt
R. S. Hyde
Miss B. J. Johnson
D. S. Johnson
Walter Jones
W. B. Kouwenhoven
P. D. Lamson
F. W. Lee
B. E. Livingston
W. T. Longcope
Mrs. R. S. Lynch
S. O. Mast
E. B. Mathews
E. V. McCollum
P. D. Meader
Adolf Meyer
S. R. Miller
J. R. Miner
Frank Morley
F. D. Murnaghan
W. A. Patrick
Raymond Pearl
A. H. Pfund
M. W. Pullen
E. E. Reid
G. H. Robinson
C. E. Simon
J. T. Singewald, Jr.
J. C. Smallwood
C. D. Snyder
R. A. Spaeth
G. L. Streeter
F. H. Swett
W. M. Thornton, Jr.
H. W. Waterfall
L. H. Weed
W. H. Welch
J. B. Whitehead
J. W. Williams
G. B. Wislocki

Professor A. G. Christie accepted the charter and responded on behalf of the chapter.

The following charter members were initiated as active members at this time:

E. A. Andrews
F. H. Baetjer
E. W. Berry
Knight Dunlap
W. W. Ford
J. E. Gilpin
J. H. Gregory
L. S. Hurlburt
Miss D. J. Johnson
W. B. Kouwenhoven
P. D. Lamson
F. W. Lee
Mrs. R. S. Lynch
S. O. Mast
E. B. Mathews
S. R. Miller
M. W. Pullen
E. E. Reid
H. W. Waterfall
L. H. Weed
J. B. Whitehead

With Professor Mast acting as secretary *pro tem* the chapter proceeded to elect officers to serve for the remainder of the academic year. The election resulted as follows:

President: A. G. Christie
Vice-president: P. D. Meader
Secretary-treasurer: G. H. Cartledge

President Christie took the chair. It was moved and carried that a committee be appointed to prepare a set of by-laws. The president appointed Messrs Dunlap, Kouwenhoven and Wislocki.

On motion the remainder of the business was postponed until after dinner. Thirty of the members were present at dinner, with the national officers and President Goodnow, of the university, as guests.

After dinner Dean Ellery addressed the chapter on the history and significance of the society, referring particularly to the new membership requirements, the numerical and territorial growth of the society, and the widening field of its activities. At the conclusion of the address there was an informal discussion of numerous details in connection with the conduct of the chapter.

The chair then introduced President Goodnow, who felicitated the chapter and spoke appreciatively of the purposes of the Sigma Xi.

The principal address was made by President Richtmyer, his subject being, "Faraday and Maxwell, and Modern Physics." Using these investigators as illustrations, he spoke very entertainingly of the obligations which we owe to the pioneers in research.

By a rising vote the chapter expressed its appreciation of the presence and services of the national officers.

G. H. CARTLEDGE,
Secretary

THE AMERICAN CHEMICAL SOCIETY

THE general program of the sixty-seventh meeting of the American Chemical Society, held in Washington, from April 21 to 26, is as follows:

MONDAY, APRIL 21

Registration, Council Meetings.

TUESDAY, APRIL 22

10:00 a. m.

The convention welcomed by R. S. McBride, president of the Washington Section of the society, who then surrenders the chair to Dr. Leo H. Backeland, president of the society.

GENERAL ADDRESSES

Robert A. Millikan, professor of physics, California Institute of Technology, "The Atom as seen by the Physicist."

Gilbert N. Lewis, professor of chemistry, University of California, "The Atom as seen by the Chemist."

2:00 p. m.

Special General Divisional Programs

Chemistry of Medicinal Products.
Industrial and Engineering Chemistry.
Organic Chemistry.
Physical and Inorganic Chemistry

4:30 p. m.

Tea at residence of Dr. and Mrs. Atherton Seidell.

8:00 p. m.

New National Museum. (1) Motion picture, "Boat Trip through Grand Canyon," with narrative by Roland W. Burchard, of U. S. Geological Survey party which made this exploration. (2) Reception.

WEDNESDAY, APRIL 23

Divisional and Sectional Meetings.
Sightseeing bus trip and luncheon for ladies.
Excursions to Government Laboratories.

8:00 p. m.

Address, "The Expansion of Chemistry," by Edwin E. Slosson, followed by social evening with music and refreshments—large and small ball rooms, New Willard Hotel. Admission by badge or by guest ticket.

THURSDAY, APRIL 24

9:30 a. m.—Divisional and Sectional Meetings.

12:30 p. m.—It is expected that the society and guests will be received by the president.

2:30 p. m.—Excursion to Mount Vernon.

6:30 p. m.—Group and fraternity functions.

7:30 p. m.—Technical and popular motion pictures, shown by Department of Agriculture and by Bureau of Mines.

FRIDAY, APRIL 25

9:30 p. m.—Divisional and Sectional Meetings.

1:30 p. m.—Division Meetings (concluded). Excursions to Government Laboratories.

4:00 p. m.—Tea for ladies. Mrs. Charles L. Parsons, hostess.

7:00 p. m.—Subscription Dinner and Dance.

SATURDAY, APRIL 26

All day Excursion to Edgewood Arsenal, Md. Special train leaves Edgewood to reach New York in time for Garvan Dinner.

SCIENTIFIC NOTES AND NEWS

AT the annual meeting of the National Academy of Sciences, to be held in Washington on April 28, the new building of the National Academy and the National Research Council will be dedicated. The president of the academy, Professor A. A. Michelson, will preside and it is understood that President Coolidge will make an address. Dr. John C. Merriam, president of the Carnegie Institution of Washington, will

speak for the National Academy, and Dr. Vernon Kellogg, secretary of the National Research Council, will speak for the council. Professor T. H. Morgan, of Columbia University, will give an address in the afternoon on "The physiological basis of heredity." In the evening there will be a reception given by the officers and members of the National Academy of Sciences and the National Research Council.

THE John Fritz Gold Medal was presented to Dr. Ambrose Swasey, of Cleveland, at a public ceremony in the Engineering Societies Building, New York, on April 23, for achievement as a designer and manufacturer of instruments and machines of precision, a builder of great telescopes, a benefactor of education and the founder of Engineering Foundation. Addresses were made by Charles F. Rand, Dr. William Wallace Campbell, General William Crozier and Dr. John R. Freeman. Representatives of engineering societies and other organizations from all parts of the country were present.

SIR F. W. MOTT, formerly Fullerian professor of physiology at the Royal Institution, has been elected a member of the Athenaeum for "distinguished eminence in science."

PROFESSOR LEO, of the chair of pharmacology at the University of Bonn, celebrated his seventieth birthday on March 27.

IT is announced that General C. G. Bruce, leader of the Mount Everest expedition, has been compelled to leave the expedition for a time on account of an attack of malaria. General Bruce, however, is convalescent, and it is hoped he may be able to rejoin the expedition before long.

CALVERT TOWNLEY, of New York, vice-president of the Westinghouse Electric and Manufacturing Company, has been named chariman of the public affairs committee of the American Engineering Council. Other members are L. P. Alford and F. B. Jewett, of New York; Professor D. C. Jackson, of the Massachusetts Institute of Technology, and Fred J. Miller, member of the Pennsylvania Public Service Commission.

THE Wisconsin Academy of Sciences, Arts and Letters held its fifty-fourth annual meeting at the University of Wisconsin on April 11 and 12. At this meeting the following officers were elected for a term of three years: *President,* Leon J. Cole; *Vice-presidents,* Sciences, S. A. Barrett, Arts, H. E. Cole, Letters, Arthur Beatty; *Secretary-treasurer,* Chancey Juday.

DR. ERWIN F. SMITH was elected president of the American Association for Cancer Research at the seventeenth annual meeting, held in Buffalo on April 17, under the presidency of Dr. William Duane. Dr. Channing C. Simmons, Boston, was elected vice-president, and Dr. Wm. H. Woglom, of Columbia University, secretary-treasurer. There was a full attendance, twenty-two papers being presented before the meeting, only two of which were by title. The society is composed largely of experimental workers in cancer, but also welcomes clinicians interested in the subject. Its organ, the *Journal of Cancer Research,* now in its eighth volume, will hereafter be published by the Croker Institute of Columbia University, under the editorial management of Dr. Francis Carter Wood.

AT a meeting of the Franklin Institute, Philadelphia, on April 16, a statement was made relative to the work of Charles A. Coffin, LL.D., past president, General Electric Company, Schenectady, New York, by Samuel Insull, Sc. D., president of the Commonwealth Edison Company, Chicago, and a certificate of honorary membership was presented to Dr. Coffin. Dr. Theodore W. Richards, director of the Wolcott Gibbs Memorial Laboratory of Harvard University presented a paper on "Compressibility, internal pressure and atomic magnitudes."

THE committee on scientific Research of the American Medical Association had awarded its grant No. 69, to the amount of $400, to Dr. Linda B. Lange, of the School of Hygiene and Public Health, Johns Hopkins University, to aid her work on diet in experimental tuberculosis.

OWING to lack of time, Irwin G. Priest, of the Bureau of Standards, has resigned as secretary of the Optical Society of America. Professor F. K. Richtmyer, Cornell University, will serve as secretary *pro tem* until further notice.

FRANK L. THOMAS, acting entomologist of the Alabama Experiment Station, has been appointed chief entomologist of the Experiment Station and state entomologist of Texas, the appointment becoming effective on May 1. He succeeds Dr. M. C. Tanquary, who has resigned in order to engage in commercial beekeeping and will have headquarters in Fargo, North Dakota.

DR. A. J. LANZA has been appointed executive officer of the National Health Council, succeeding Dr. D. B. Armstrong, who resigned on January 1. Dr. Lanza takes this position after three years' absence in Australia where he assisted in the organization of the Commonwealth Health Department. The National Health Council comprises twelve leading national voluntary health agencies, together with the United States Public Health Service and the United States Children's Bureau as conference members.

DR. LOUIS NAVIAS, in the past year a special expert

in the Ceramic Division of the U. S. Tariff Commission, has joined the research staff of the General Electric Company at Schnectady, N. Y., as ceramic chemist.

DR. E. P. CHURCHILL, of the University of South Dakota, will act as adviser to the director of the U. S. Bureau of Fisheries Biological Station, Fairport, Iowa, in the planning and conduct of the freshwater mussel investigations to be carried on this season under the direction of this station.

PROFESSOR W. B. HERMS, of the University of California, left San Francisco on the motor schooner *"Doris Crane,"* on April 10, for Fanning Island, where he will study cocoanut pests. While in the South Seas, Professor Herms will also carry out a general survey of the fauna and flora of Fanning and other neighboring islands. Harold Kirby, fellow in zoology, will assist in the work. The investigation will extend over a period of about four months.

DR. FRANK D. KERN, dean of the graduate school and head of the botany department at the Pennsylvania State College, has been called by the Porto Rican government to make a special study of fungi in Porto Rico during the coming summer.

J. L. KING, who recently returned from Japan after three years study of the parasites of the green Japanese beetle, is now appointed as specialist in charge of the division of parasites, at the Japanese Beetle Laboratory, Riverton, New Jersey.

SURGEON-GENERAL HUGH S. CUMMING has sailed for Europe to inspect the activities of U. S. Public Health Service officers stationed in foreign consulates and to attend the meeting of the Office international d'hygiene publique. He will also attend an immigration conference to be held at Rome, May 15. During the absence of Surgeon-General Cumming, Assistant Surgeon-General M. J. White, the ranking officer of the bureau, will be in charge.

PROFESSOR EDWIN G. CONKLIN, of Princeton University, on March 4, delivered a public address under the auspices of the Society of Sigma Xi of Syracuse University, on "Recent reactions against evolution."

DR. GEORGE H. PARKER, professor of zoology in Harvard University, is announced as the speaker who will address the annual banquet of the Phi Beta Kappa Society at Williams College on May 9.

DR. HARRY N. HOLMES, of Oberlin College, recently lectured on "Emulsions" and on "Gels" at Yale, Princeton, the University of Pennsylvania, Brown and at Schenectady before the General Electric staff.

DR. I. NEWTON KUGELMASS, of Yale School of Medicine, addressed the Johns Hopkins Medical Society on "Physico-chemical studies of the mechanism of blood coagulation" on April 7.

DR. JEROME ALEXANDER, of New York City, addressed the Buffalo and Niagara Falls Sections of the American Chemical Society on "The importance of impurities," on April 15, and on April 16 spoke at the University of Buffalo on "Colloids."

ON the afternoon of April 3, Professor John Henry Comstock, of Cornell, gave an address on "Early entomologists and their work," in the lecture room of the department of entomology of Stanford University. The lecture was attended by a number of the professors and students of the University of California and of Stanford University, and by some of the entomologists of the California Academy of Sciences and others of the San Francisco Bay region. In the evening a dinner was given at the Stanford Union in honor of Professor and Mrs. Comstock. After the dinner Professor and Mrs. Comstock both gave interesting talks. Dr. David Starr Jordan, chancellor emeritus of Stanford University, one of Dr. Comstock's first students in entomoloy, and others also gave very interesting talks.

DR. C. V. L. CHARLIER, professor of astronomy and director of the observatory of the University of Lund, gives the Hitchcock lectures at the University of California this year. The general subject is "The structure of the universe," and the titles of the lectures are: "Historical introduction," "Star gauges of William Herschel," "The milky way," "Steady stellar systems," "An infinite world." He will also offer a course in the intersession on "The motion of the stars," and one in the summer session on "The distribution of the stars."

THERE will be a series of three lectures by Professor Leonor Michaelis, Aichi University, Ikadaigaku, Nagoya, Japan, on "The electrifying effect of ions; an essay of a general theory, with especial application to biology," under the auspices of The Institute of Medicine of Chicago and the University of Chicago on the evenings of April 30, May 1 and May 2, in Kent Theater at the University of Chicago.

MEDICAL experts from England, Germany and Holland are directing short courses in neurology from April 7 to May 30 under the auspices of the Department of Neurology of the School of Medicine and University Extension of the College of Physicians and Surgeons of Columbia University. Dr. Alfons Jakob, University of Hamburg, is offering lectures and laboratory demonstrations in neuro-pathology. Dr. G. V. Anrep, University College of London, is giving a course on the physiology of the cortex as investigated by the method of conditioned reflexes. A course in the morphology of the central nervous sys-

tem is being given by Dr. C. U. Ariens Kappers, director of the Central Brain Institute, Amsterdam.

FRANCIS JEFFREY BELL, formerly professor of comparative anatomy in King's College, London, and assistant in the British Museum, died on April 1, in his seventieth year.

COUNT HILAIRE DE CHARDONNET, who first devised processes for making artificial silk, died in Paris on March 12, in his eighty-fourth year.

THE ninth Italian Geographical Congress will take place this year at Genoa from April 22 to 30. *The Geographical Journal* writes: Such meetings of Italian geographers were inaugurated in 1892 by an assembly in the same city of Genoa, summoned in order to commemorate the fourth centenary of the discovery of America. The present congress is organized by the National Italian Geographical Committee, lately formed in affiliation with the International Geographical Union. Besides the general meetings, there will be meetings of six sections which are to deal with the several branches of the subject, and eight exhibitions are being organized, several of which will be specially concerned with Liguria under various aspects, physical and historical.

STATE engineers from a number of the commonwealths interested in superpower plans conferred with Secretary of Commerce Hoover on April 14, and it was agreed that they will lay before the public service commissions of their respective states the facts which have been developed. On the basis of these facts it is hoped that the public service commissions may be induced to suggest legislation which would facilitate and encourage the interstate flow of electrically produced power.

WE learn from the *Journal* of the American Medical Association that the Ella Sachs Plotz Foundation for the Advancement of Science has been established in memory of Ella S. Plotz, of New York. The available annual income is $10,000. For the present, research will be favored that is directed toward the solution of medical problems. Grants may be used to purchase apparatus and supplies for special investigations, and for unusual expenses incident to such investigations, including technical assistance. The trustees of the fund desire to receive applications for grants for work on problems of practical medicine and surgery, preventive medicine and the medical science. Plans for a concerted attack by a group of investigators, working either at one center or in different places, on some problem of serious import in medicine, will be especially welcomed. Applications for support from this foundation should be accompanied by a full statement of the need for the investigation, the conditions under which it is to be done, and the way in which the grant would be expended. Applications should be forwarded to the secretary of the executive committee, Dr. Francis W. Peabody, Boston City Hospital, Boston. Other members of the executive committee are Drs. Walter B. Cannon, Bernard Sachs and Paul J. Sachs.

WE learn from *Nature* that the Royal Society has received from a donor, who desires to remain anonymous, a gift of £10,000, for the prosecution of original research in medicine for the prevention of disease and relief of suffering, with special attention to tropical diseases in British possessions and to cancer and tuberculosis. They have also received from Messrs. Brunner, Mond and Co., a gift of 500 guineas to be used for the publication of the results of scientific research in chemistry, physics and similar sciences.

THE British Ministry of Agriculture announces that Oxford University has accepted its proposal to set up a separate research institute in agricultural engineering. The university has chosen as director of the new institute Captain B. J. Owen, who for some time past has taken an important part in connection with the ministry's machinery research. The ministry proposes that tests of agricultural machinery shall be carried out and certificates issued on its authority, but that the actual work of testing shall be conducted by the new Oxford Institute, the National Physical Laboratory and other institutions.

THE Werner-Siemens Institute for Röntgen Research is to be opened on March 22. The city of Berlin, in collaboration with the firm of Siemens & Halske, has established here a large teaching and research institute with modern equipment. The city will pay the current expenses, and Siemens & Halske will furnish, at their expense, the apparatus and instruments. A joint board of control appointed by the founders will administer the institute. It will serve, primarily, for practical, clinical research work, and, secondarily, the whole field of röntgenology. Dr. Frik, formerly assistant at the first university medical clinic in Berlin, has been chosen director.

UNIVERSITY AND EDUCATIONAL NOTES

A BEQUEST of $100,000 to Williams College is made in the will of William A. Swift, of the class of 1863. A condition of the bequest is that $1,200 of the income be used each year for four scholarships of $300 each.

YALE University announces the gift of $2,000 for the establishment of the Charles Lathrop Pack Foundation, the income to be given annually as a prize for the best original article or story of popular interest on some forestry subject by a student.

THE British Minister of Agriculture on April 7 laid the foundation stone of a new building for the department of agriculture of Leeds University, which is to be built at the cost of £60,000.

AT a public meeting at Kingston organized by university men it was agreed that all sections of the people should be asked to support an appeal to the Secretary of State in favor of founding a West Indian University at Jamaica. It was proposed, further, to solicit imperial assistance for the scheme, which provides for the setting up of an examining body in the West Indies at Codrington College, Barbados, and at the Agricultural College of Trinidad, which would be branches of the university.

PROFESSOR CHRISTIAN A. RUCKMICK, associate professor of psychology in Wellesley College, has been elected professor of psychology in the State University of Iowa.

PROFESSOR A. E. JOLLIFFE has been appointed to the university chair of mathematics tenable at King's College, London. Since 1920 he has been university professor of mathematics at Royal Holloway College.

DISCUSSION AND CORRESPONDENCE

CONCERNING THE VARIATIONS OF ATMOSPHERIC ELECTRICITY AND VERTICAL CURRENTS

I AM sure that Dr. Sanford will concede that my criticism[1] of his theory[2] of the annual variation of the potential gradient of atmospheric electricity was a courteous one. Instead of entering into a discussion of the ideas advanced by him, I confined my remarks to calling attention to data, apparently not accessible to him, which did not support his theory. In the last sentence of the first paragraph of his recent article,[3] he gives an incomplete interpretation of a statement of mine by failing to give it in its entirety. Dr. Sanford's theory had implied that generally over the earth the annual variation at a given place should primarily vary according to the sine of the sun's zenith distance at apparent noon, and I attempted to show that this theory did not fit the facts as we *now* know them, for widely-separated regions. No blame was attached to him for not being in possession of the latest literature; however, as he knows, from my correspondence with him, the Department of Terrestrial Magnetism is at all times ready to keep him informed of latest developments, if he desires such assistance. Were it necessary other facts, not in accord with Dr. Sanford's theory, could be cited. Moreover, it is found that wherever there are available simultaneous observations of the potential gradient and of the electric conductivity, the product of the two quantities, or the vertical current density, follows about the same course during the year as does the potential gradient itself.

Dr. Sanford has also some rather fixed ideas regarding the cause of the diurnal variation of atmospheric electricity, and it would seem as though he has taken an unreceptive attitude towards modern developments that are not in accord with his theories. He cites[2] in support of his ideas, theories and conclusions reached by eminent investigators, 50 years and more ago, when the science of atmospheric electricity was in its infant state, and many of the noted advances of the past two decades were unknown. In the September, 1923, issue of *Terrestrial Magnetism and Atmospheric Electricity* will be found a general summary by my colleague, Dr. S. J. Mauchly, of the principal facts regarding the diurnal variation of the potential gradient of atmospheric electricity, as derived from the available observations on the oceans and at land stations.

Respecting the question as to the existence of vertical electric currents as disclosed by line integrals of the magnetic force, or by analyses of the earth's permanent and transient magnetic fields, Dr. Sanford goes back to results of investigations made 20 years and more ago, before the extensive data accumulated on our ocean cruises, by our land expeditions and by cooperating institutions, were available. The manner of carrying out our computations of line integrals and the interpretation of the signs of the resulting values are in accord with those adopted by eminent physicists.

Any one looking carefully over my various statements, especially those in recent papers, will see that I have not failed to recognize the physical difficulties and that I have diligently pointed out the quantitative discrepancy between the current densities as obtained from the magnetic line integrals and the observations in atmospheric electricity. Furthermore, the endeavor has been made to find some other physical interpretation of the results than that of vertical electric currents, and it may be that when the exhaustive analysis of the earth's magnetic field, in progress at the Department of Terrestrial Magnetism, has been completed, some other physical explanation, as, for example, a relativity effect, will be found sufficient to account for the outstanding "non-potential system." When the analysis has been completed, we shall then be able also to map out this non-potential system, or the geographical distribution of equivalent vertical-current effects, which will supersede the 1920 results quoted by Dr. Sanford, for which the avail-

[1] SCIENCE, July 27, 1923, pp. 67–68.
[2] SCIENCE, May 25, 1923, pp. 616–618.
[3] SCIENCE, February 22, 1924, pp. 194–196.

able observational data, largely because of delays caused by the late war, were still not as extensive as they are now. The 1920 results had been distinctly designated as *preliminary* ones, which fact Dr. Sanford has apparently overlooked. However, the results of the computations to date, though differing somewhat in detail from those for 1920, support the general conclusions previously drawn. The non-potential system besides being unsymmetrical about the axis of rotation is also found to be unsymmetrical about the equator, hence we must not expect, as did Dr. Sanford, that the computations of magnetic line-integrals along corresponding parallels of latitude on opposite sides of the equator should give identical results. The combination of results for corresponding parallels, north and south, was made with the view of obtaining approximately the system symmetrical about the equator. The difficulties encountered in finding an adequate physical explanation of non-potential effects are minor as compared with those which arise when attempting to explain the origin of the earth's magnetic field in the manner Dr. Sanford has attempted.

LOUIS A. BAUER

WASHINGTON, D. C.

CAVERNS IN THE GUADALUPE MOUNTAIN RANGE

IT is evident from the note on the "Carlsbad Cavern in New Mexico" in SCIENCE for December 14, 1923, that Dr. Lee and Mr. Holley are not well acquainted with the early history of that cavern.

The writer met at Carsbad, New Mexico, in the autumn of 1914, a Mr. Borden, then superintendent for the Los Angeles fertilizer concern then working the guano deposits of the Carlsbad cavern. Mr. Borden described to the writer an exploring trip which he had made in the cave which occupied the time from early one Saturday until the afternoon of the following Monday, the work of exploration being continuous during that interval of time except for the intervals necessary for sleeping and eating.

In the summer of 1918, Dr. N. F. Drake, then state geologist of Arkansas and professor of geology, University of Arkansas, and the writer explored the cavern for a distance of about three fourths of a mile from its main entrance. At that time they were informed that the then superintendent in charge of the guano extraction had succeeded in reaching a distance estimated to be ten miles from the mouth of the cavern, but had not found its end.

There are other notable cavern in this same Guadalupe mountain range. One is found in Slaughter Canyon about two miles from its mouth and was visited by us. In its vicinity there were formerly other great caverns later filled in by travertine deposits. At the time of our examination of the region two wells were being drilled on the eastern flanks of the Guadalupe Mountains. One of them encountered a cavern from which a continuous current of cold air issued. The other well was six miles distant from the first. The driller had his hat sucked down the hole when the drill broke into a cavern in this well. Another large cavern was reported to have been found near where the Carlsbad-Queen road crosses the summit of the Guadalupe Mountains.

Other notable caverns occur in the San Andreas limestone of the Sacramento Mountains, the next range north of the Guadalupe. Three days after the summer rains of 1918 began on the summit of the Sacramento Mountains in the vicinity of Cloudcroft wells in the vicinity of Roswell, some 70 miles distant, which previously it had been necessary to pump, began to flow out at the surface. It is likely that the water derived from the rainfall in the mountain summits reached the wells 70 miles away in three days and travelled a considerable part of the distance through underground caverns.

CHARLES LAWRENCE BAKER

THE FLASHING OF FIREFLIES

THE articles in SCIENCE on "The synchronous flashing of fireflies"[1] might lead one to infer that knowledge of this peculiar phenomenon is a recent contribution to science. I have in my possession a textbook studied by my grandfather. This book, called "An Easy Grammar of Geography," was published in Philadelphia in the year 1810. The author is Reverend J. Goldsmith. May I quote paragraph 187 on Siam?

> The elephants of Siam are distinguished for sagacity and beauty. The trees on the banks of the Meinam River are finely illuminated with swarms of fire-flies, which *emit and conceal their light as uniformly as if it proceeded from a machine of the most exact contrivance.*

The italics are mine.

HESTER L. VAN VLECK

MADISON, WISCONSIN

JOSEPH LEIDY

DR. OSBORN, in his address at the Leidy Centenary (SCIENCE, Feb. 22, 1924), referred to Dr. Leidy's breadth of knowledge. This was shown in his ready comments upon the varied papers read before the Academy of Natural Science in Philadelphia. I recall one evening in the early eighties one of the members read an elaborately prepared paper upon the origin of the name of the arbor vitae, taking the accounts of the early Canadian pioneers, and their use of the arbor vitae branches for their beds, and of the

[1] SCIENCE, Vol. LIII, p. 485 (1921); LIX, 163 (1924).

health-giving qualities of the tree, as possibly having suggested to them the name arbor vitae, tree of life. When the speaker had sat down, Dr. Leidy, in his quiet manner, said that such and such a Latin physiology published some time in 1600, refers to a small filament at the base of the brain, which from its tree-like form was called arbor vitae, the tree of life, and that he had always assumed that the great similarity of this filament to the form of the arbor vitae had led to the tree's name. Thus it was that Leidy from his broad and profound knowledge would bring out some such point which the writer of an elaborate paper had overlooked. In this case the writer being *only* a botanist was not aware of the filament at the base of the brain.

R. C. CANBY

EXHIBITION OF THE ROYAL PHOTOGRAPHIC SOCIETY

THE Royal Photographic Society of Great Britain are holding their sixty-ninth annual exhibition in September and October of this year. This is the most representative exhibition of photographic work in the world, and the section sent by American scientific men heretofore has sufficiently demonstrated the place held by this country in applied photography. It is very desirable that American scientific photography should be equally well represented in 1924, and, in order to enable this to be done with as little difficulty as possible, I have arranged to collect and forward American work intended for the scientific section.

This work should consist of prints showing the use of photography for scientific purposes and its application to spectroscopy, astronomy, radiography, biology, etc. Photographs should reach me not later than Saturday, June 14. They should be mounted but not framed. There are no fees.

I should be glad if any worker who is able to send photographs will communicate with me as soon as possible so that I may arrange for the receiving and entry of the exhibit.

A. J. NEWTON

EASTMAN KODAK COMPANY,
ROCHESTER, N. Y.

SCIENTIFIC BOOKS

A Comprehensive Treatise on Inorganic and Theoretical Chemistry. Vol. IV.—Ra and Ac Families, Be, Mg, Zn, Cd, Hg. By J. W. MELLOR. 1074 pages. Longmans, Green and Co., London, 1923. Price, $20.00.

VOLUME IV of the "Comprehensive Treatise" represents an important addition to the volumes already published. (For review of Vols. I–III, see SCIENCE, Vol. 58, No. 1500, (1923)). This is particularly true because of the fact that the treatment of the radioactive elements is expanded to include a discussion of the modern theories of atomic structure and valence, which were omitted entirely from the chapters on valence and similar subjects in Vol. I. The first chapter deals with the structure of matter, treated broadly and historically; the second treats the radioactive elements; and the third is entitled "The Architecture of the Atom." A very considerable amount of data is given, and the references are full and apparently up to date. The author makes no attempt to correlate conflicting theories, a task which is, after all, better left to monographs on the subject. The student will find in these chapters much to interest and stimulate him.

The remaining chapters are devoted to an exhaustive study of the elements listed on the title page. Beryllium and magnesium are treated separately; zinc and cadmium together; mercury separately. The method of treatment is similar to that employed in the earlier volumes. Each element is taken from the most remote reference to it in literature, and is brought down to quite recent dates, with abbreviated statements of apparently almost all the work that may have been done, and with very full references. In the opinion of the reviewer the book would have been improved if a somewhat more critical attitude had been taken, more space being given to apparently reliable data, and less to some of the older data. Nevertheless, these abbreviated statements must arouse the interest and curiosity of the student perhaps even *because* of their failure to give full information, and the frequent absence of logical sequence. Thus, " . . . , the electric sparking of cadmium under liquid argon produces a voluminous olive-green powder, which . . . is thought to be a nitride. According to O. Sackur, the catalytic activity of the following metals on the combustion of hydrogen decreases in order Ag, Pt, Cu, Pb, Zn, Ni, Sn, Fe, Cr." Altogether, Volume IV maintains very satisfactorily the standard set by the earlier volumes.

GRAHAM EDGAR

UNIVERSITY, VIRGINIA

SPECIAL ARTICLES

A SIMPLE METHOD FOR QUANTITATIVE STUDIES OF IONIZATION PHENOMENA IN GASES

DIRECT measurements of the free paths of electrons in gases and a great deal of other quantitative information regarding the mechanism of ionization may be obtained from a simple type of tube which contains no grid. A straight tungsten *filament, f,* is mounted

in the axis of a *cylindrical electrode, c.* Fitting within the ends of the cylinder, but without touching it, are two *end plates, a* and *b* with their planes perpendicular to the axis of the cylinder. The filament, *f,* whose effective length is the same as the distance between the end plates, passes through small holes in the centers of these plates. In most of the experiments the cylinder has been 4 cm. long and 3.2 cm. in diameter.

As an example, let the tube contain mercury vapor at a pressure of 200 bars (0.15 mm). Apply a potential of + 100 volts to *a* and — 10 volts to *c* and *b,* these being measured from the negative end of the filament. Heat the filament to a temperature at which it emits 10 milliamps. of electrons. A positive ion current of 19 m.a. is collected by *c* and this current, which is independent of the negative potential applied to *c,* is a measure of the positive ion current density (0.51 m.a. per cm.^{2}) within the ionized gas.[1] The positive ion sheath covering the inner surface of the cylinder is only 0.9 mm. thick.

Taking into account the relatively large masses of the mercury ions, it can be shown that the average velocities of the ions in the ionized gas must be less than 3×10^5 cm. per sec. and from this it may be calculated that the number of ions per cm.^{3} must exceed $6. \times 10^{11}$ which is about 4,000 times as great as the average density due to the primary electrons from the filament.

The low speed electrons produced by ionization accumulate within the gas until this positive ion space charge is nearly neutralized. The "electron current density" in the gas (in all directions!) is then about 640. m.a. per cm.^{2} which is 180. times greater than the actual current density to the anode *a.* The anode must, therefore, be negative (actually about 6.5 volts) with respect to the gas, *i.e.,* the anode drop is negative. The anode (at + 100 volts!) thus collects as many *positive ions* as a similar electrode (say *b*) at — 50 volts.

The conductivity of the ionized gas, calculated from well-known mobility equations, is so high that a current of 10 m.a. can flow the length of the tube without causing a drop in potential of more than 0.1 volt. The positive ion density, because of the greater primary electron current density, must increase as we pass to points nearer the axis of the cylinder. There must be corresponding differences in the electron densities and these must be brought about by the development of potential differences in these regions whose magnitude can be calculated by the Boltzmann equation.

$$\rho = \rho_0 \epsilon^{\frac{Ve}{kT}}$$

where V is the potential difference in volts between two regions in which the electron densities are ρ and ρ_0 respectively. The constant e/k has the value 11,600 degrees per volt; and T is the temperature corresponding to the electron velocities, (15,000° in the case we are considering.)

There is thus within the ionized gas a radial field (about 1 volt difference of potential) which tends to accelerate the positive ions outwards towards *c,* even if *c* is made the anode. This probably explains the fact that the density of the positive ion current collected by *c* is usually 2 to 4 times as great as that to *b* (both electrodes being at negative potentials). In the example considered the ion current to *b* was 1.7 m.a. and we may assume that an equal current of ions was collected by the anode. Calculation from the space charge equations shows that the ion current to the filament can not have exceeded 0.7 m.a. The total ion current to all electrodes was therefore $19 + 2 \times 1.7 + 0.7$ or 23.1 m.a. and these ions were produced by the action of 10 m.a. of primary electrons. Thus 2.31 ions were produced by each electron. Let us denote this ratio by β.

The primary electrons from the filament are strongly accelerated within the sheath around the filament so that when they have traveled a distance equal to the thickness of the sheath (0.4 mm.) they have acquired the full velocity corresponding to the cathode drop (107.5 volts in our example). They then move in strictly radial directions with constant velocity until they collide with atoms or reach the edge of the sheath on the cylinder *c.* In this latter case they penetrate a certain distance within the sheath, but are exposed to a retarding field and if *c* is at a negative potential they are all thrown back out of the sheath, and again move in a radial direction with the original velocity. The electrons thus continue to move back and forth without loss of energy until they collide with atoms or reach the anode because of longitudinal velocities arising from geometrical imperfections in the tube.

If the cylinder *c* is brought to a *positive potential* the retarding field in the sheath is no longer able to prevent primary electrons from reaching *c.* At pressures low enough for an appreciable fraction, γ, of the electrons to reach the collector *c* without having collided with atoms, there is thus an abrupt and accurately measurable change Δ in the current to *c* when the potential is raised from negative values to positive values of one or two volts.[2]

This change, Δ, is due to two factors: (1) the electrons taken up by *c,* and (2) the decrease in the ion current resulting from the removal of these elec-

[1] Langmuir, SCIENCE, Vol. 58, p. 290 (1923).

[2] The potential drop along the filament has been eliminated in many of the experiments by intermittent heating of the filament with a rotating commutator.

trons.[3] It is readily shown that

$$\gamma = \frac{\triangle}{1 - r + \beta_c}$$

where r is the fraction of electrons reaching c which are reflected (about 20 per cent. in the present experiments) and β_c is that part of β which corresponds to positive ion current flowing to c when this electrode is negative ($\beta_c = 1.9$ in our example).

The quantity γ is related to the mean free path λ of the electrons by the equation

$$\gamma = \epsilon^{-c/\lambda}$$

or since the free path is inversely proportional to the pressure p,

$$\gamma = \epsilon^{-cp/\lambda_1}$$

Here c is the radius of the cylinder c and λ_1 is the free path at unit pressure.

The principal source of error lies in the determination of the temperature or density of the gas in the tube. To avoid uncertainty of this kind, tubes are now used with a metallic deposit on the glass wall of the tube itself, used as the collecting cylinder c.

A study of the current-voltage curves obtained with electrodes a and b gives practically full information regarding the number and distribution of velocities of the electrons in the ionized gas. The data obtained in experiments with argon and mercury vapor permit the recognition of 5 distinct classes of electrons in the ionized gas.

Class I. Primary Electrons from Cathode.—These move radially with constant velocity. The mean free path λ, of 50 volt electrons, in argon at 347°K reduced to a pressure of 1 bar, is 69. cm. This free path is practically independent of the energy of the primary electrons between 30 and 225 volts and agrees well with that calculated from the kinetic theory from viscosity measurements (*i.e.*, $4\sqrt{2}$ times the free path of argon *atoms*).

Class II. Electrons Scattered through Small Angles by Elastic Collisions.—About 9 per cent. of the collisions between 100 volt electrons and argon atoms are elastic in the sense that the electrons lose no energy. Over half of these collisions, however, cause the electrons to be deflected through angles of less than 8° and practically none of them result in deflections greater than 15°. The number of collisions resulting in this small angle scattering decreases from about 20 per cent. for 30 volt electrons to 5 per cent. for 225 volt electrons. In mercury vapor no electrons of Class II were observed.

Class III. Electrons which suffer a Definite Energy Loss.—About 24 per cent. of the collisions between 100 volt electrons and argon atoms cause a loss of 13. ± 1 volt energy to the electron and these electrons are deflected through an average angle of about 10°, a few per cent. only suffering deflections as great as 20°. The fraction of collisions giving Class III electrons varies with the velocity of the primary electrons as follows: 0.26 for 50 volt; 0.21 for 150 volts and 0.13 for 225 volt electrons. The energy loss in collisions yielding Class III electrons in *mercury vapor* corresponds to 6.7 volts in agreement with data of Eldridge (*Phys. Rev. 20*, 456, (1922)). They never appear to lose energy corresponding to the ionizing potential (10.4 volts). About 36 per cent. of the collisions of 100 volt electrons with mercury atoms yield Class III electrons and the angular deflections are about the same as with argon.

Class IV. Secondary Electrons of Moderate Velocity.—These electrons move nearly in random directions and have velocities distributed according to Maxwell's law corresponding to a temperature T_4. The current density I_4 (through any imaginary plane from one side to the other) serves as a measure of the number of such electrons. For example, with argon at 44 bars and the anode at 100 volts, with a primary emission of 10 m.a. I_4 was found to be 0.12 m.a. per cm.^{2} and T_4 was 310,000° which corresponds to an average energy for the Class IV electrons of 40 volts. The number of such electrons produced is usually considerably smaller than the number of primaries. It is believed that Class IV electrons are not a direct result of collisions between primary electrons and atoms but are more probably due to photo-electric emission from gas atoms due to ultraviolet radiation from atoms excited by primary electrons. In general, the velocities and number of these electrons decrease as the pressure is raised and increase as the anode voltage is raised.

Class V. Secondary Electrons of Low Velocity.—These electrons move in random directions and with Maxwellian distribution of velocities and have average energies ranging from 0.7 volts at high pressures (1,000 bars) to 10 volts at lower pressures (30 bars) and higher voltages (225 volts). The number of these electrons per unit volume is several thousands of times greater than the number in any other class and it is principally these electrons which neutralize the positive ion-space charge.

The total production of electrons of Classes IV and V must equal the rate of positive ion production measured by β. (β = positive ions per primary electron). The values of β rise from o at the ionizing potential about in proportion to the anode voltage up to about 150 volts and then increase somewhat more slowly. The total ionization β increases only slowly with the pressure. Thus with argon and an anode voltage of 100, β is 1.2 at 20 bars, 1.45 at 50 bars, 1.7 at 100 bars, 1.95 at 300 bars and then de-

[3] This is confirmed by the simultaneous change in positive ion current to b. This changes in the ratio $1 : 1 - \gamma$.

creases at higher pressures probably as a result of recombination. With mercury vapor, the values of β are about 50 per cent. greater.

These results indicate that 60 or even 70 per cent. of the primary electrons lose nearly all of their energy on their first collisions with atoms and the remaining atoms lose energy less than that needed to produce ionization. Since 2 or 3 ions may be formed by each electron it appears that the primary process involved in ionization by 30 to 200 volt electrons is the production of an *excited* atom or ion which takes up nearly the whole energy of the incident electron. Then, by collisions with other atoms, or more probably by radiation, this excited atom causes the ionization of several other atoms.

This mechanism seems essentially different from that postulated in a recent paper by R. H. Fowler (Phil. Mag. *47*, 257 (1924)).

The foregoing results confirm nearly all the conclusions drawn by Eldridge in his study of the ionization of mercury vapor.

Experiments are in progress using hydrogen, helium, nitrogen, neon and carbon monoxide.

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PLURISEGMENTAL INNERVATION OF SKELETAL MUSCLE FIBERS AND IMPLICATIONS CONCERNING FATIGUE

THE traditional picture of the fiber of skeletal muscle represents it as receiving one motor nerve-fiber which is assumed to be connected with it near its middle point. Text-books of histology[1] sometimes refer to the possible innervation of a single muscle-fiber by two or more nerve-fibers, but the impression is usually conveyed that this is an atypical condition. Physiologists have pointed out that the complete involvement of a muscle-fiber in the process of contraction must be secured more promptly when stimulation is made to take effect at two places than when it is restricted to one. But a simple calculation shows that any such gain in speed of developing contraction can be only slight even if the spacing of the myoneural junctions is ideal. Other aspects of reduplicated innervation brought out some years ago by Agduhr[2] have been too little regarded.

This observer discovered that in cases where a muscle in the leg of a mammal can be made to contract by stimulating either of two motor nerve-roots it may develop nearly as much tension in response to the excitation of one root as when both are stimulated at the same time. This would not be the case if each fiber in the muscle could be reached by one and only one nerve-path. The alternative, Agduhr considered, must be an organization of the motor system such that the same muscle-fibers can be called into action by distinct efferent elements. The arrangement indicated he has denominated plurisegmental innervation.

Agduhr sought and found histological evidence of such a relation. Making use of cats and rabbits he performed experiments in which the principle applied was one of differential degeneration. After sectioning a certain motor nerve-root, he kept the animals alive for from 58 to 144 hours. Postmortem preparations of particular muscles then showed normal and partially degenerated nerve-fibers in the same fields. Again and again pairs of myoneural junctions were seen upon single muscle-fibers. These were not widely separated as though adapted to insure more speedy responses, but usually close together. Most significant was the fact that where two nerve-fibers were traced to endings in one muscle-fiber the criterion of degeneration showed that they were derived from separate spinal nerves.

In this communication we desire to make a preliminary report on some experiments which were originally undertaken to see whether such a type of organization is to be found in the frog as well as in the mammal. They have been fruitful of suggestions which we did not at all anticipate. The gastrocnemius lends itself conveniently to such a study. The sciatic nerve of the frog, as observed near the spinal cord, is found to be represented by three strands. Two of these generally contribute to the motor innervation of the gastrocnemius. There is considerable variation in the relative size of these two bundles of fibers, but in many cases they are nearly equal. When this is true, it has been our experience that the contractions of the selected muscle evoked by stimulating the two components alternately are also of about the same magnitude. This holds for simple or tetanic, isotonic or isometric responses.

When we compare the tension developed by the gastrocnemius when one of the nerve divisions is stimulated with the tension recorded when both are excited at the same time it becomes apparent that but little is gained by calling in the second system to assist the first. In other words, Agduhr's experiment succeeds with the frog as well as with the mammal. Examples of this may be cited. Calling the two divisions of the nerve A and B, we note in

[1] Piersol, "Normal Histology," 1916, 86. Lewis and Stöhr's "Text-book of Histology," 1913, 163.

[2] Agduhr, *Anat. Anzeiger*, 1916, XLIX, 1–13; 1919, LII, 273. Also Wilson, *Brain*, 1921, XLIV, 234.

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one case that the tension of the muscle during tetanic stimulation of A is 45 grams, with B it is 40 grams, and with both together only 48 grams. Again: A alone gives 30 grams, B alone 45 grams, and both together 50 grams. Our inference is necessarily the same as Agduhr's, namely, that the majority of the muscle-fibers have a plurisegmental innervation.

Fatigue Phenomena.—Since we can call most of the working units of the gastrocnemius into action by stimulating about half its motor nerve-fibers, it is possible to make fatigue records with this procedure and then to shift our excitation to the second motor component. The result is singularly clean cut. When we stimulate one division of the motor nerve with single shocks or with a tetanizing current until the muscle has practically ceased to respond, we can rouse it to renewed activity by transferring our stimulation to the other division. A second series of contractions of the same order and duration as the first can generally be secured.

What are we to conclude from the facts at hand? If we had only the data of fatigue we should explain the result very simply: we should say that the motor fibers of the first component brought one set of muscle-fibers into action and that those of the second component presided over a distinct set which had remained at rest during the contractions of their fellows. But we know from our measurements of tension that nearly all the muscle-fibers have been active from the outset. It seems impossible to escape the conclusion that what we have fatigued is not the mechanism of contraction, but something which serves to transmit the stimulus. Such fatigue has been commonly held to occur at the myoneural junction or end-plate and the present finding is consistent with the prevalent impression. But it is probably premature to single out a specific anatomical structure as the precise seat of the change. All that we know is that a stage of fatigue exists at which certain avenues of approach to the work-part of the muscle are blocked while others remain open.

Sherrington[3] and Forbes[4] showed some years ago that a similar state of fatigue is often demonstrable in the central nervous system. Certain afferent paths may become ineffective, while others remain available for the production of reflexes. The inference has been that such fatigue is synaptic. Physiologists have accordingly recognized the possibility of renewing reflex activity when it is flagging by the employment of new channels of access to the centers, but they have not hitherto considered that muscle-fibers also may have alternative approaches.

[3] "Integrative Action of the Nervous System," 1906, 218.

[4] *American Journal of Physiology*, 1912, XXXI, 102.

It must be borne in mind that when we excite muscle through its nerve we can not truly increase the strength of the stimulation which is brought to bear upon the contractile units by increasing our electric current. We can not force the nerve-impulse above a fixed intensity. If the threshold of the muscle rises to such a level that nerve-impulses fail of effect, we can not surmount it by any modification of indirect stimulation. We can, however, lead our stimulating current through the muscle itself and compel it to resume activity. There are two ways in which this result may conceivably be secured: the current may break over the elevated threshold at the original sites or it may find its way to other places where there has been no previous metabolism to induce fatigue. When we are making use of direct stimulation we can repeatedly force the contractions of a declining muscle nearly to their initial height by intensifying the shocks. The most probable explanation of this possibility would seem to be the following: To intensify the current sent through a tissue is equivalent to shifting and multiplying its points of effective application (physiological kathodes). It is more difficult than is generally assumed to be sure that all the resources of a muscle have been exhausted. We are convinced that fatigue in laboratory preparations usually consists in a resistance to the transmission of the excitatory process and that fatigue of this type can be quite sharply localized.

This conception has an odd corollary. If we are right in our belief that muscular activity is most prolonged when different points of attack are utilized successively, it is to be anticipated that supramaximal stimulation will exhaust a large part of the excitatory apparatus prematurely and thus limit the possibility of later shifting. We have obtained some evidence that this is the case. According to the same reasoning, we shall get more work out of a gastrocnemius when we stimulate adequately first one and then the other of its two nerve-components than when we play upon the whole nerve at once. When we excite nerve-fibers which end in muscle elements whose innervation is already provided for by other motor connection, we must be using up the equipment to no useful purpose.

The facts have an interesting bearing on human fatigue, endurance and training. On the clinical side they must affect the prevailing judgment as to the extent of degeneration and probable recovery in such diseases as poliomyelitis.

McKEEN CATTELL,
PERCY G. STILES

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